

(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

**EP 0 947 235 A1**

(12)

**EUROPEAN PATENT APPLICATION**

(43) Date of publication:  
06.10.1999 Bulletin 1999/40

(51) Int. Cl.<sup>6</sup>: **B01D 53/94**

(21) Application number: 99106526.9

(22) Date of filing: 30.03.1999

(84) Designated Contracting States:  
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU  
MC NL PT SE  
Designated Extension States:  
AL LT LV MK RO SI

(30) Priority: 31.03.1998 JP 8482098  
22.09.1998 JP 26759798

(71) Applicant:  
MAZDA MOTOR CORPORATION  
Aki-gun, Hiroshima 735 (JP)

(72) Inventors:  
• Ueoka, Toshitsugu  
Higashihiroshima-shi, Hiroshima (JP)  
• Kurokawa, Takahiro  
Hiroshima-shi, Hiroshima (JP)  
• Murakami, Hiroshi  
Hiroshima-shi, Hiroshima (JP)  
• Watanabe, Yasuto  
Iwakuni-shi, Hiroshima (JP)

(74) Representative:  
Zinnecker, Armin, Dipl.-Ing. et al  
Lorenz-Seldier-Gossel,  
Widenmayerstrasse 23  
80538 München (DE)

**(54) Exhaust gas purifying catalyst**

(57) An exhaust gas purifying catalyst comprises a first catalyst disposed in an exhaust gas stream for oxidizing NO to NO<sub>2</sub> and a second catalyst disposed in the exhaust gas stream downstream from the first catalyst for reducing the oxidized NO<sub>2</sub> which clacks HC having a large carbon number to HC having a small carbon number and causes the clacked HC to react with NO<sub>2</sub> so as thereby to reduce the NO<sub>2</sub>.

EP 0 947 235 A1

## Description

[0001] This invention relates to an exhaust gas purifying catalyst suitable for lowering an emission level of NO<sub>x</sub> in an exhaust gas with an oxygen concentration greater than 10 % from a diesel engine and an exhaust gas with a high oxygen concentration such as greater than 4 % produced as a result of combustion of a lean fuel mixture with an air-to-fuel ratio greater than 22 in a lean burn engine.

[0002] One of exhaust gas purifying catalysts described in, for example, Japanese Unexamined Patent Publication No. 63 - 49255 comprises two parts, namely a first catalyst disposed in an exhaust gas stream for oxidizing NO to NO<sub>2</sub> and a second catalyst disposed in the exhaust gas stream downstream from the first catalyst for catalyzing reduction of NO<sub>2</sub> to N<sub>2</sub> have been known in the art. This exhaust gas purifying catalyst employs metals such as Ag and Mn, an oxide of Cu or halogenide for the first catalyst and zeolite for the second catalyst. Another one of exhaust gas purifying catalysts described in, for example, Japanese Unexamined Patent Publication No. 8 - 278131 comprises three parts, namely a first catalyst containing Ag supported on one of alumina and titania, a second catalyst containing Ag, Cu or Ni supported on one of alumina, titania, zeolite, silica and zirconia, and a third catalyst a metal such as Pt supported on one of alumina, titania, zeolite, silica and zirconia. The first catalyst is disposed in an exhaust gas stream and works to oxidize NO to NO<sub>2</sub>, and a mixture of the second and third catalysts is disposed in the exhaust gas stream downstream from the first catalyst and works to catalyze reduction of NO<sub>2</sub>. Still another exhaust gas purifying catalyst described in, for example, Japanese Unexamined Patent Publication No. 8 - 192050 comprises two parts, namely a first catalyst containing Ag, Co or Ni supported on alumina and a second catalyst containing Ag supported on mordenite. The first catalyst is disposed in an exhaust gas stream and works to oxidize NO to NO<sub>2</sub>, and the second catalyst is disposed in the exhaust gas stream downstream from the first catalyst and works to catalyze reduction of NO<sub>2</sub>. A further exhaust gas purifying catalyst described in, for example, Japanese Unexamined Patent Publication No. 9 - 299795 comprises two parts, namely a first catalyst containing Pt supported on alumina disposed in an exhaust gas stream for oxidizing NO to NO<sub>2</sub> and a second catalyst containing Pt and Ba supported on alumina disposed in the exhaust gas stream downstream from the first catalyst for adsorbing NO<sub>2</sub> and catalyzing reduction of adsorbed NO<sub>2</sub>.

[0003] These prior art exhaust gas purifying catalysts work to oxidize NO in an exhaust gas to NO<sub>2</sub>, and then to catalyze reduction of NO<sub>2</sub> for decomposition. In order to effectively cause reduction of NO<sub>2</sub>, it is effective to utilize a reducing agent with a high activity and to oxidize NO to NO<sub>2</sub> with a high efficiency. For purification of NO, there are two process. One of the two processes is to

reduce and decompose NO<sub>2</sub> after oxidizing NO to NO<sub>2</sub>. Another process is to directly reduce and decompose NO. In order to achieve more efficient purification of NO, the later process can not be disregarded. In the cases where exhaust gases contain sulfide, it is necessary to prevent catalytic components from being poisoned with the sulfide.

[0004] The present invention has its object to provide an exhaust gas purifying catalyst which can significantly lower the emission level of NO in an exhaust gas with a high oxygen concentration.

[0005] An exhaust gas purifying catalyst of the invention comprises a first catalyst for oxidizing NO to NO<sub>2</sub> in exhaust gases and a second catalyst for reducing the oxidized NO<sub>2</sub> in the exhaust gas. The second catalyst clacks HC having a large carbon number (e.g. 12 to 20) to HC having a small carbon number such as olefin and causes the clacked HC to react with NO<sub>2</sub> so as thereby to reduce the NO<sub>2</sub>. Because of the clacking function of the catalyst, the NO<sub>2</sub> oxidized by the first catalyst is efficiently reduced under existence of the HC having a small carbon number which has a high activity on the second catalyst. The first catalyst preferably contains at least one selected out of catalytic metals Ag, Co and Mn. Each catalytic metal may be supported alone or in combination with any one of the remaining catalytic metal. A combination of two catalytic metals Ag and Co improves NO-to-NO<sub>2</sub> conversion efficiency of the catalyst or prevents aggravation of NO<sub>x</sub> purification efficiency due to sulfur compounds, for example preventing Ag from being poisoned with a sulfide. Alumina, mesopore-silicate and FAU zeolite, alone or in combination, are preferably used as a base material.

[0006] The first catalyst may further contain at least one selected out of catalytic metals Ni, Ce, Rh and Fe with an effect of improving NO-to-NO<sub>2</sub> conversion efficiency and increasing resistance to sulfuration. Especially, a combination of Ag and Ni as the first catalytic metal provides a significant increase in NO-to-NO<sub>2</sub> conversion efficiency and great improvement of resistance to sulfuration. In this instance, the first catalyst preferably contains 20 to 60 g per one liter substrate of Ag and 20 to 50 g per one liter substrate of Ni.

[0007] In the case where the first catalyst contains a combination of Ag and Co as catalytic metals, the first catalyst may comprise an under catalyst layer containing Ag as a catalytic metal coated on a substrate and an over catalyst layer containing Co as a catalytic metal coated over the under catalyst layer, which provides an effect of significant increasing NO-to-NO<sub>2</sub> conversion efficiency and greatly improving resistance to sulfuration.

[0008] On the other hand, the second catalyst may contain a catalytic metal supported on a metal silicate through ion exchange. This is because it has a superior HC clacking function, the ion exchange increases dispersion of the catalytic metal, and the catalytic metal is made easy to attract NO<sub>2</sub> due to electrical charge devi-

ation. A noble metal such as Pt may be used as a preferable catalytic metal. It is to be noted that the zeolite on which a catalytic metal such as Pt is supported through ion exchange not only reduces and decomposes NO<sub>2</sub> but also directly reduces and decomposes NO. Accordingly, the reducing function of the second catalyst in cooperation with the oxidizing function of the first catalyst provides significantly improved NO<sub>x</sub> purification efficiency.

[0009] As apparent from the above, it can be said that an exhaust gas purifying catalyst is preferred for high NO conversion efficiency to comprise a combination of a first catalyst containing at least one selected out of catalytic metals Ag, Co and Mn and a second catalyst containing a noble metal represented by Pt supported on metal silicate represented by zeolite through ion exchange. An exhaust gas purifying catalyst comprising a first catalyst containing Ag as a catalytic metal is especially preferable.

[0010] In the case where an exhaust gas purifying catalyst comprises a combination of a first catalyst containing Ag as a catalytic metal and a second catalyst containing a noble metal supported on metal silicate through ion exchange, it is preferred to form the first and second catalysts in the form of individual layers on a substrate. This is because Ag particles dispersed near noble metal particles impose an adverse effect on the activity of the noble metal. In this instance, it is preferred to dispose the first catalyst in an exhaust gas stream upstream from the second catalyst.

[0011] According to another embodiment of the invention, the exhaust gas purifying catalyst for oxidizing NO to NO<sub>2</sub> in an exhaust gas contains least one selected out of catalytic metals Ag and Co and at least one selected out of catalytic metals Ni and Ce in combination. In this instance, the catalytic metal Ni or Ce works effectively as a promotor or additive to promote oxidation of NO to NO<sub>2</sub>, so as thereby to provide an increase in NO-to-NO<sub>2</sub> conversion efficiency and improve resistance to sulfuration of Ag and Ce.

[0012] According to still another embodiment of the invention, the exhaust gas purifying catalyst containing Ag as a catalytic metal further contains at least one selected out of catalytic metals Ni, Ce, Rh, Ce and Fe with an effect of further improving NO-to-NO<sub>2</sub> conversion efficiency.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The foregoing and other objects and features of the invention will become apparent to one having ordinary skill in the art from the following description directed to preferred embodiments thereof when reading in conjunction with the accompanying drawings, in which:

Figure 1 is a schematic block diagram showing an exhaust gas purifying catalyst according to an

embodiment of the invention;

Figure 2 is a graph showing the relationship between inlet temperature and NO<sub>x</sub> purification efficiency for sample exhaust gas purifying catalysts according to an embodiment of the invention and a comparative exhaust gas purifying catalyst;

Figure 3 is a graph showing C300 and maximum NO<sub>x</sub> purification efficiency for different sample exhaust gas purifying catalysts comprising different first catalysts;

Figure 4 is a graph showing NO conversion efficiency with respect to inlet temperature for different first catalysts;

Figure 5 is a graph showing C300 and maximum NO<sub>x</sub> purification efficiency for sample exhaust gas purifying catalysts comprising different second catalysts;

Figure 6 is a graph showing catalytic exhaust gas purification efficiency for a sample exhaust gas purifying catalyst according and a exhaust gas purifying comparative catalyst actually installed on a vehicle;

Figure 7 is a graph showing maximum NO-to-NO<sub>2</sub> conversion efficiency with respect to Ag content of an Ag/Al<sub>2</sub>O<sub>3</sub> catalyst;

Figure 8 is a graph showing C250, C300 and maximum NO-to-NO<sub>2</sub> conversion efficiency for an Ag/Al<sub>2</sub>O<sub>3</sub> catalyst and simultaneous impregnation type of sample Ag/Al<sub>2</sub>O<sub>3</sub> first catalysts before sulfuration treatment;

Figure 9 is a graph showing C250, C300 and maximum NO-to-NO<sub>2</sub> conversion efficiency for an Ag/Al<sub>2</sub>O<sub>3</sub> catalyst and simultaneous impregnation type of sample Ag/Al<sub>2</sub>O<sub>3</sub> first catalysts after sulfuration treatment;

Figure 10 is a graph showing C250, C300 and maximum NO-to-NO<sub>2</sub> conversion efficiency for a simultaneous impregnation type of first catalysts and a separate impregnation type of first catalysts before sulfuration treatment;

Figure 11 is a graph showing C250, C300 and maximum NO-to-NO<sub>2</sub> conversion efficiency for a simultaneous impregnation type of first catalysts and a separate impregnation type of first catalysts after sulfuration treatment;

Figure 12 is a schematic cross-sectional view of a layered type of first catalyst;

Figure 13 is a graph showing C250, C300 and maximum NO-to-NO<sub>2</sub> conversion efficiency for an Ag/Al<sub>2</sub>O<sub>3</sub> first catalyst and a layered type of first catalysts before sulfuration treatment;

Figure 14 is a graph showing C250, C300 and maximum NO-to-NO<sub>2</sub> conversion efficiency for an Ag/Al<sub>2</sub>O<sub>3</sub> first catalyst and a layered type of first catalysts after sulfuration treatment;

Figure 15 is a graph showing C250 and maximum NO-to-NO<sub>2</sub> conversion efficiency with respect to Ni content of an Ag-Ni/Al<sub>2</sub>O<sub>3</sub> first catalyst before and

after sulfuration treatment; and,

Figure 16 is a graph showing C250 and maximum NO-to-NO<sub>2</sub> conversion efficiency with respect to Ag content of the Ag-Ni/Al<sub>2</sub>O<sub>3</sub> first catalyst before and after sulfuration treatment.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0014] In the following description, the term "C250 NO conversion efficiency" as used herein shall mean and refer to efficiency of NO-to-NO<sub>2</sub> conversion of an exhaust gas purifying catalyst at an inlet temperature of 250°C, the term "C300 NO conversion efficiency" as used herein shall mean and refer to efficiency of NO-to-NO<sub>2</sub> conversion of an exhaust gas purifying catalyst at an inlet temperature of 300°C, and the term "Cmax temperature" as used herein shall mean and refer to an inlet temperature at which an exhaust gas purifying catalyst shows maximum efficiency of NO-to-NO<sub>2</sub> conversion.

[0015] Referring to the drawings in detail and, in particular, to Figure 1 showing a structure of an exhaust gas purifying catalyst 1 of the invention suitable for a diesel engine, the catalyst 1 comprises a first or upstream catalyst 2 disposed in an exhaust gas stream Ex after a diesel engine Eg and a second or downstream catalyst 3 disposed in the exhaust gas stream Ex adjacent to and downstream from the first catalyst 2. The first catalyst 2 works to oxidize NO to NO<sub>2</sub>, and the second catalyst 3 works to catalyze reduction of the NO<sub>2</sub>. These first and second catalysts may be formed separately on a single substrate or on separate substrates. Further, the first and second catalysts 2 and 3 may be formed in layers on a single substrate. If the first and second catalysts 2 and 3 interfere in catalytic function with each other, they are formed in layers with a buffer layer intervened between the first and second catalyst layers. If the first and second catalysts 2 and 3 do not interfere in catalytic function with each other, they may be supported as a mixture on a substrate.

[0016] As an example (marked SC12) of the exhaust gas purifying catalyst 1, the first catalyst 2 consists of an Ag/Al<sub>2</sub>O<sub>3</sub> catalyst in which Ag as a catalytic noble metal is supported on an alumina base material, and the second catalyst 3 consists of a Pt\*-MFI catalyst in which Pt as a catalytic noble metal is supported on an MFI zeolite (composite zeolite ZSM-5) base material by ion exchange.

[0017] In preparation of the Ag/Al<sub>2</sub>O<sub>3</sub> catalyst, a  $\gamma$ (gamma)-alumina powder having a high specific surface area as a base material and a hydrated alumina powder as a binder were mixed with a weight ratio of 10 : 1, and the mixture was added with water to provide a mixture slurry. A honeycomb substrate, which had a volume of 25 mL, 400 cells per square inch and a wall of 0.006 inch thickness, was dipped in and drawn from the mixture slurry and dried in an oven. The process was repeated until 150 g/L (150 g per one lit. of substrate) of

the alumina base material was supported as a layer on the honeycomb substrate. The alumina layer on the honeycomb substrate 1 was impregnated with a specified quantity of solution which was prepared by dissolving a silver nitrate in deionized water and dried at 200°C in an oven and then calcined at 500°C for two hours in an electric furnace to support 0.44 mol/L Ag on the honeycomb substrate. The first catalyst contained impurities less than 1 %. In the following description, the impurities content of a catalyst is always less than 1 %.

[0018] In preparation of the Pt\*-MFI catalyst as the second catalyst 3, a H-type of MFI zeolite (ZSM-5 made by PQ Corporation) having a salic ratio of 30 was thrown in water, and then stirred and heated until the solution attained a temperature of 80°C. Subsequently, the MFI zeolite solution was mixed with a specified quantity of solution of hexamine-platinum-tetrachloride (Pt(NH<sub>3</sub>)<sub>6</sub>Cl<sub>4</sub>), and the solution mixture was stirred and heated for three hours, and thereafter cooled and filtered to provide a solid mixture. The solid mixture was rinsed and dried to provide a powder of the mixture. The mixture powder was finally calcined at 350°C for two hours to prepare the Pt\*-MFI catalyst.

[0019] The Pt\*-MFI catalyst powder and hydrate alumina powder were mixed with a weight ratio of 10 : 1, and the mixture was added with water to provide a mixture slurry. A honeycomb substrate, which had a volume of 25 mL, 400 cells per square inch and a wall 0.006 inch thickness, was dipped in and drawn from the mixture slurry, and dried in an oven. The process was repeated until 150 g/L of the Pt\*-MFI catalyst powder was supported as a layer on the honeycomb substrate. In this instance, the Pt\*-MFI catalyst layer contained 0.3 g/L Pt. In order to make NOx purification efficiency measurements, the first and second catalysts 2 and 3 were installed in an exhaust gas flow tunnel apparatus in order from the upstream side. The inlet temperature of exhaust gas was increased at a rate of 25°C/min. An exhaust gas was simulated as follows and circulated through the apparatus at a space velocity of 85000/h.

HC : 170 ppmC (dodecane C<sub>12</sub>H<sub>26</sub>)

O<sub>2</sub> : 10 %

CO : 200 ppm

NO : 170 ppm

H<sub>2</sub>O : 5 %

CO<sub>2</sub> : 4.5 %

N<sub>2</sub> : Reminder

[0020] Figure 2 summarizes the result of NOx purification efficiency measurements for the sample exhaust gas purifying catalyst 1 together with a comparative

exhaust gas purifying catalyst which was comprised of Pt<sup>+</sup>-MFI first and second catalysts. As apparent from Figure 2, the sample exhaust gas purifying catalyst 1 comprising the Ag/Al<sub>2</sub>O<sub>3</sub> first catalyst and the Pt<sup>+</sup>-MFI second catalyst shows high NO<sub>x</sub> purification efficiency at exhaust gas temperatures higher than approximately 240°C.

[0021] For sample exhaust gas purifying catalysts SC1 through SC12 comprised of different first catalysts and the Pt<sup>+</sup>-MFI second catalysts, respectively, NO<sub>x</sub> purification efficiency measurements were made under the same condition excepting that the inlet temperature of simulated exhaust gas was increased at a rate of 25°C/min after holding the simulated exhaust gas at 160°C for five minutes. The result of NO<sub>x</sub> purification efficiency measurements is summarized in Figure 3 in which C300 and Cmax indicate NO<sub>x</sub> purification efficiency of the exhaust gas purifying catalyst at an inlet temperature of 300°C and maximum NO<sub>x</sub> purification efficiency of the exhaust gas purifying catalyst.

[0022] The respective sample exhaust gas purifying catalysts SC1 to SC12 were comprised of the following first and second catalysts.

Sample exhaust gas purifying catalyst SC1

[0023]

First catalyst: Co-Ce/H-FAU  
H-type FAU zeolite as a base material was impregnated with catalytic metals Co and Ce simultaneously.  
Second catalyst: Pt<sup>+</sup>-MFI

Sample exhaust gas purifying catalyst SC2

[0024]

First catalyst: Ag-Ni/Al<sub>2</sub>O<sub>3</sub>  
γ-alumina as a base material was impregnated with catalytic metals Ag and Ni simultaneously.  
Second catalyst: Pt<sup>+</sup>-MFI

Sample exhaust gas purifying catalyst SC3

[0025]

First catalyst: Co/H-FAU  
H-type FAU zeolite as a base material was impregnated with a catalytic metal Co.  
Second catalyst: Pt<sup>+</sup>-MFI

Sample exhaust gas purifying catalyst SC4

[0026]

First catalyst: Ag/H-β  
H-type β-zeolite as a base material was impreg-

nated with a catalytic metal Ag.

Second catalyst: Pt<sup>+</sup>-MFI

Sample exhaust gas purifying catalyst SC5

[0027]

First catalyst: Ag/H-FAU  
H-type FAU zeolite as a base material was impregnated with a catalytic metal Ag.  
Second catalyst: Pt<sup>+</sup>-MFI

Sample exhaust gas purifying catalyst SC6

[0028]

First catalyst: Ag/MPS  
Mesopore silicate (crystal silicate having 1 to 24 nm diameter of pores) as a base material was impregnated with a catalytic metal Ag.  
Second catalyst: Pt<sup>+</sup>-MFI

Sample exhaust gas purifying catalyst SC7

[0029]

First catalyst: Ag/H-MFI  
H-type MFI zeolite as a base material was impregnated with a catalytic metal Ag.

Second catalyst: Pt<sup>+</sup>-MFI

Sample exhaust gas purifying catalyst SC8

[0030]

First catalyst: Ag-Co/Al<sub>2</sub>O<sub>3</sub>  
γ-alumina as a base material was impregnated with catalytic metals Ag and Co simultaneously.  
Second catalyst: Pt<sup>+</sup>-MFI

Sample exhaust gas purifying catalyst SC9

[0031]

First catalyst: Ag-Rh/Al<sub>2</sub>O<sub>3</sub>  
γ-alumina as a base material was impregnated with catalytic metals Ag and Rh simultaneously.  
Second catalyst: Pt<sup>+</sup>-MFI

Sample exhaust gas purifying catalyst SC10

[0032]

First catalyst: Mn/Al<sub>2</sub>O<sub>3</sub>  
γ-alumina as a base material was impregnated with a catalytic metal Ag.

Second catalyst: Pt<sup>+</sup>-MFI

Sample exhaust gas purifying catalyst SC11

[0033]

First catalyst: Co/Al<sub>2</sub>O<sub>3</sub>

γ-alumina as a base material was impregnated with a catalytic metal Co.

Second catalyst: Pt<sup>+</sup>-MFI

Sample exhaust gas purifying catalyst SC12

[0034]

First catalyst: Ag/Al<sub>2</sub>O<sub>3</sub>

γ-alumina as a base material was impregnated with a catalytic metal Ag.

Second catalyst: Pt<sup>+</sup>-MFI

Comparative exhaust gas purifying catalyst CC13

[0035]

First catalyst: Pt<sup>+</sup>-MFI

Second catalyst: Pt<sup>+</sup>-MFI

[0036] The exhaust gas purifying catalyst comprising the first catalyst containing a single catalytic metal was prepared in the same manner as the first catalyst 2 (Ag/Al<sub>2</sub>O<sub>3</sub>) of the sample exhaust gas purifying catalyst SC12 described above. Specifically, 150 g/L base material and 0.44 mol/L catalytic metal were supported on a 25 mL honeycomb substrate. The exhaust gas purifying catalyst comprising the first catalyst containing two catalytic metals was prepared by impregnating the base material with salts of the catalytic metals dissolved in deionized water and then drying and calcining it. The total amount of two catalytic metals contained in the first catalyst was 0.22 mol/L.

[0037] As apparent from Figure 3, the sample exhaust gas purifying catalysts SC1 to SC12 comprising the first catalyst which contains either one of catalytic metals Ag, Co and Mn show greater C300 NOx purification efficiency than the comparative exhaust gas purifying catalyst (marked CC13 in Figure 3) comprising the Pt<sup>+</sup>-MFI first catalyst and have maximum NOx purification efficiency approximately equal to or greater than that of the comparative exhaust gas purifying catalyst CC13. This fact indicates that a catalyst containing either one of catalytic metals Ag, Co and Mn works as the first or upstream catalyst with improved NOx purification efficiency. A comparison of the sample exhaust gas purifying catalysts SC4 through SC7 and XII containing Ag as a catalytic metal in the first catalyst with one another reveals that alumina is prominent as a base material. A comparison of the sample exhaust gas purifying cata-

lysts SC2, SC8, SC9 and SC12 with one another reveals that a combination of Ag with another catalytic metal such as Rh and, in particular, Ni is desirable to be used together with an alumina base material of the first catalyst. Further, a comparison of the sample exhaust gas purifying catalysts SC3 and SC11 which contains Co as a catalytic metal in the first catalyst with one another reveals that FAU zeolite is prominent as a base material. As apparent from a comparison of the sample exhaust gas purifying catalysts SC1 and SC3, a combination of catalytic metals Co and Ce with an FAU zeolite base material provides remarkably improved NOx purification efficiency.

[0038] The sample exhaust gas purifying catalysts SC3 through SC12 have Cmax temperatures approximately 100°C higher than the comparative exhaust gas purifying catalyst CC13 comprising the Pt<sup>+</sup>-MFI first catalyst. This fact suggests that the NOx purification activity is developed in different ways between the sample exhaust gas purifying catalysts SC3 through SC12 and the comparative exhaust gas purifying catalyst CC1. That is, according to the inventor's experimental and experiential understanding is that the comparative exhaust gas purifying catalyst CC13 comprising Pt<sup>+</sup>-MFI first and second catalysts only converts NO for the most part by directly reducing and decomposing NO and that since, while each sample exhaust gas purifying catalysts SC3 - SC12 has a Pt<sup>+</sup>-MFI second catalyst, it has a first catalyst having the function of oxidizing NO to NO<sub>2</sub> disposed upstream from the Pt<sup>+</sup>-MFI second catalyst, the Pt<sup>+</sup>-MFI second catalyst has the function of reducing and decomposing NO<sub>2</sub> produced by the first catalyst in addition to the function of directly reducing and decomposing NO. This is well substantiated by measurements of NO conversion efficiency, the result of which is shown in Figure 4.

[0039] NO conversion efficiency measurements were made for the first or upstream catalysts of the sample exhaust gas purifying catalysts SC1 - SC3, SC8 - SC10 and SC12 under the same condition as the NOx purification efficiency measurements. In this instance, however, the inlet temperature of simulated exhaust gas was increased at a rate of 25°C/min after holding the simulated exhaust gas at 150°C for five minutes. As seen in Figure 4, each sample exhaust gas purifying catalysts have inlet temperatures for the maximum NO conversion efficiency agreeing with the maximum temperature, accurately or approximately, for NOx purification efficiency (shown in Figure 3), respectively.

[0040] For sample exhaust gas purifying catalysts SC14 through SC23 comprising the Ag/Al<sub>2</sub>O<sub>3</sub> first catalysts and different second catalysts, respectively, NOx purification efficiency measurements were made under the same condition excepting that the inlet temperature of simulated exhaust gas was increased at a rate of 25°C/min after holding the simulated exhaust gas at 160°C for five minutes. The result of C300 NOx purification efficiency and Cmax temperature measurements is

summarized in Figure 3.

[0041] The respective sample exhaust gas purifying catalysts SC14 through SC23 were comprised of the following first and second catalysts.

Sample exhaust gas purifying catalyst SC14

[0042]

First catalyst: Ag/Al<sub>2</sub>O<sub>3</sub>

Second catalyst: Pt<sup>+</sup>-MFI • Pt/H-MFI

Sample gas purifying catalyst SC15

[0043]

First catalyst: Ag/Al<sub>2</sub>O<sub>3</sub>

Second catalyst: Pt<sup>+</sup>-MFI

(This sample was the same as the sample exhaust gas purifying catalyst SC12)

Sample exhaust gas purifying catalyst SC16

[0044]

First catalyst: Ag/Al<sub>2</sub>O<sub>3</sub>

Second catalyst: Pt-Ir/H-MFI

H-type MFI zeolite as a base material was impregnated with catalytic metals Pt and Ir simultaneously.

Sample exhaust gas purifying catalyst SC17

[0045]

First catalyst: Ag/Al<sub>2</sub>O<sub>3</sub>

Second catalyst: Au/H-MFI

H-type MFI zeolite as a base material was impregnated with a catalytic metal Au.

Sample exhaust gas purifying catalyst SC18

[0046]

First catalyst: Ag/Al<sub>2</sub>O<sub>3</sub>

Second catalyst: Ir/H-MFI

H-type MFI zeolite as a base material was impregnated with a catalytic metal Ir.

Sample exhaust gas purifying catalyst SC19

[0047]

First catalyst: Ag/Al<sub>2</sub>O<sub>3</sub>

Second catalyst: Rh/H-MFI

H-type MFI zeolite as a base material was impregnated with a catalytic metal Rh.

5 Sample exhaust gas purifying catalyst SC20

[0048]

First catalyst: Ag/Al<sub>2</sub>O<sub>3</sub>

10

Second catalyst: Pt/H-β

H-type β-zeolite as a base material was impregnated with a catalytic metal Pt.

15 Sample exhaust gas purifying catalyst SC21

[0049]

First catalyst: Ag/Al<sub>2</sub>O<sub>3</sub>

20

Second catalyst: Pt/H-MFI

H-type MFI zeolite as a base material was impregnated with a catalytic metal Pt.

Sample exhaust gas purifying catalyst SC22

25

[0050]

First catalyst: Ag/Al<sub>2</sub>O<sub>3</sub>

30

Second catalyst: Pt/Al<sub>2</sub>O<sub>3</sub>

γ-alumina as a base material was impregnated with a catalytic metal Pt.

Sample exhaust gas purifying catalyst SC23

35

[0051]

First catalyst: Ag/Al<sub>2</sub>O<sub>3</sub>

Second catalyst: Ag/Al<sub>2</sub>O<sub>3</sub>

40

γ-alumina as a base material was impregnated with a catalytic metal Ag.

[0052] Sample exhaust gas purifying catalyst SC14 was prepared by mixing Pt<sup>+</sup>-MFI catalyst powder and Pt/H-MFI catalyst powder with a weight ratio of 1 : 1 and wash-coating the mixture on a 25 mL honeycomb substrate such that the total weight of the base materials was 150 g/L and the amount of Pt was 0.15 g/L after ion-exchanged and 0.5 g/L after dried and solidified.

45

The second catalyst of each sample exhaust gas purifying catalyst SC15 - SC23 was prepared by spray-drying a mixture of a base material and a catalytic metal solution with a specified ratio and further drying the mixture at a temperature between 100 and 200°C for one hours and calcining it at a temperature between 500 and 600°C for two hours to provide second catalyst powder.

50

The catalyst powder was wash-coated on a 25 mL honeycomb substrate and subsequently dried at a temper-

55

ature between 100 and 200°C for one hours and calcined at a temperature between 500 and 600°C for two hours. The amounts of base material and catalytic metal of the coated second catalyst were 150 g/L and 1 g/L, respectively.

[0053] As apparent from Figure 5, the sample exhaust gas purifying catalysts SC14 and SC15 which comprise the second catalyst including Pt\*-MFI show remarkably greater C300 NOx purification efficiency and maximum NOx purification efficiency than the remaining sample exhaust gas purifying catalysts SC16 to SC23. The remaining sample exhaust gas purifying catalysts SC16 to SC22 show which comprise the second catalyst including Pt or other catalytic metals supported on MFI or H-β zeolite show C300 NOx purification efficiency and/or maximum NOx purification efficiency inferior to those of the sample exhaust gas purifying catalyst SC23 which comprises the Ag/Al<sub>2</sub>O<sub>3</sub> first and second catalysts. These facts indicate the usefulness of the Pt\*-MFI catalyst and is considered to result from supporting Pt on MFI zeolite through ion exchange. There are some reasons for the remarkably superior C300 NOx purification efficiency and maximum NOx purification efficiency of the exhaust gas purifying catalysts SC14 and SC15 which contain Pt supported as a catalytic metal on MFI zeolite through ion exchange. Specifically, the Pt\*-MFI catalyst has the function of clacking HC in an exhaust gas and then catalysing reduction of NO<sub>2</sub> with the highly activated HC, ion exchange makes Pt possible to be dispersed and supported on MFI zeolite at level of atom, which increases dispersion of Pt with an effect of improving the catalytic activity, and Pt is made easy to attract NO<sub>2</sub> due to electrical charge deviation. The same is true for catalysts which contain another catalytic metal such as Rh and Pd in place of Pt or support a catalytic metal on metal silicate in place of MFI zeolite.

[0054] In order to evaluate performance of the exhaust gas purifying catalyst of the invention, field tests were made to measure NOx and HC purification efficiency in JPN 10-15 mode of the sample exhaust gas purifying catalyst SC9 comprising the Ag-Rh/Al<sub>2</sub>O<sub>3</sub> first catalyst and the Pt\*-MFI second catalyst. The Ag-Rh/Al<sub>2</sub>O<sub>3</sub> first catalyst was coated on a 1.3 L honeycomb substrate such that it contained 30 g/L Ag and 1 g/L Rh supported by 150 g/L alumina, and the Pt\*-MFI second catalyst was coated on a 2.0 L honeycomb substrate such that it contained 0.5 g/L Pt supported by 150 g/L MFI zeolite. The comparative exhaust gas purifying catalyst CC13 comprising the Pt\*-MFI first and second catalysts. Each Pt\*-MFI catalyst was coated on a 3.3 L honeycomb substrate such that it contained 0.5 g/L Pt supported by 150 g/L MFI zeolite. Each of these sample exhaust gas purifying catalyst SC9 and comparative exhaust gas purifying catalyst CC13 was mounted on a vehicle which had an overall weight of 1,625 kg and was equipped with a diesel engine having a displacement of 1.7 L/stroke. NOx and HC concentrations in the exhaust gas from the

diesel engine were 50 to 60 ppm and 10 to 1,000 ppm, respectively. The result of the field tests is shown in Figure 6.

[0055] As apparent from Figure 6, the sample exhaust gas purifying catalyst SC9 has NOx and HC purification efficiency in JPN 10-15 mode both greater than the comparative exhaust gas purifying catalyst CC13.

[0056] Conversion of NO to NO<sub>2</sub> by the Ag-Rh/Al<sub>2</sub>O<sub>3</sub> first catalyst is a major reason for the greater exhaust gas purifying performance of the sample exhaust gas purifying catalyst SC9. In light of this, in order to evaluate the effect of Ag contents of the first Ag/Al<sub>2</sub>O<sub>3</sub> on NO conversion efficiency, maximum NO conversion efficiency measurements were made under the same condition as the NO conversion efficiency measurements for the sample exhaust gas purifying catalysts SC1 - SC3, SC8 - SC10 and SC12, the result of which is shown in Figure 4, for sample exhaust gas purifying catalysts of the invention which comprised Ag/Al<sub>2</sub>O<sub>3</sub> first catalysts having Ag contents different from one another. The Ag/Al<sub>2</sub>O<sub>3</sub> first catalyst contained alumina and binder of 130 g/L in total weight and a weight ratio of 5 : 1. The result is shown in Figure 7 in which line L indicates the maximum NO conversion efficiency of an exhaust gas purifying catalyst comprising a Pt/Al<sub>2</sub>O<sub>3</sub> first catalyst which had a 2 g/L Pt content. It is revealed from Figure 7 that the Ag content of the Ag/Al<sub>2</sub>O<sub>3</sub> first catalyst is favorable to be between 15 and 150 g/L and, more specifically, between 20 and 120 g/L.

[0057] In addition to the evaluation of the effect of Ag contents of the first Ag/Al<sub>2</sub>O<sub>3</sub> on NO conversion efficiency, the effect of a catalytic metal in combination of Ag of the first catalyst was further studied. NO conversion efficiency measurements were made for various first catalysts containing various combinations of two catalytic metals, Ag and another catalytic metal such as La, Ce, Fe, Co, Ni or Cu, supported by γ-alumina as a base material before and after sulfuration treatment. The sulfuration treatment is referred to exposing a first catalyst to an SO<sub>2</sub> gas consisting of 50 ppm SO<sub>2</sub>, 20 % O<sub>2</sub> and the remainder of N<sub>2</sub> at 350°C for 30 minutes.

[0058] NO conversion efficiency measurements were made by exposing the first catalyst to an exhaust gas flow which was increased at a rate of 30°C/min. after held at 160°C for five minutes and circulated through the exhaust gas flow tunnel apparatus at a space velocity of 85000/h. The exhaust gas was simulated as follows.

HC	: 170 ppmC (dodecane C <sub>12</sub> H <sub>26</sub> )
O <sub>2</sub>	: 10 %
CO	: 200 ppm
NO	: 170 ppm
CO <sub>2</sub>	: 4.5 %



N<sub>2</sub> : Reminder

[0059] The following sample first catalysts SCF1 to SCF7 were prepared for measurements of NO conversion efficiency before and after the sulfuration treatment.

Sample first catalyst SCF1: Ag/Al<sub>2</sub>O<sub>3</sub>

[0060]

γ-alumina as a base material was impregnated with a catalytic metal Ag.

Sample first catalyst SCF2: Ag-La/Al<sub>2</sub>O<sub>3</sub>

[0061]

γ-alumina as a base material was impregnated with first and second catalytic metals Ag and La, simultaneously.

Sample first catalyst SCF3: Ag-Ce/Al<sub>2</sub>O<sub>3</sub>

[0062]

γ-alumina as a base material was impregnated with first and second catalytic metals Ag and Ce, simultaneously.

Sample first catalyst SCF4: Ag-Fe/Al<sub>2</sub>O<sub>3</sub>

[0063]

γ-alumina as a base material was impregnated with first and second catalytic metals Ag and Fe, simultaneously.

Sample first catalyst SCF5: Ag-Co/Al<sub>2</sub>O<sub>3</sub>

[0064]

γ-alumina as a base material was impregnated with first and second catalytic metals Ag and Co, simultaneously.

Sample first catalyst SCF6: Ag-Ni/Al<sub>2</sub>O<sub>3</sub>

[0065]

γ-alumina as a base material was impregnated with first and second catalytic metals Ag and Ni, simultaneously.

Sample first catalyst SCF7: Ag-Cu/Al<sub>2</sub>O<sub>3</sub>

[0066]

γ-alumina as a base material was impregnated with first and second catalytic metals Ag and Cu, simultaneously.

[0067] In preparation of the sample first catalyst, a γ-alumina powder as a base material and a hydrated alumina powder as a binder were mixed with a weight ratio of 10 : 1, and the mixture was added with water to provide a mixture slurry. A honeycomb substrate, having a volume of 25 mL, 400 cells per square inch and a wall thickness of 0.006 inch, was dipped in and drawn from the mixture slurry and dried in an oven. The process was repeated until 150 g/L alumina base material (150 g per one lit. of substrate) was supported as a layer on the honeycomb substrate 1. The alumina layer on the honeycomb substrate 1 was impregnated with a specified quantity of a catalytic metal solution. The catalytic metal solution was prepared by dissolving a silver nitrate alone, or a mixture of a silver nitrate and a nitrate of another catalytic metal, in deionized water and dried at 200°C in an oven and then calcined at 500°C for two hours in an electric furnace. The base material coated on the honeycomb substrate was impregnated with the catalytic metal solution such that the first catalyst SCF1 contained 120 g/L γ-alumina as a base material and 30 g/L Ag, or each of the remaining first catalysts SCF2 to SCF5 contained 120 g/L γ-alumina as a base material, 30 g/L Ag and 0.44 mol/L other catalytic metal.

[0068] The result of measurements of C300, C250 and maximum NO conversion efficiency of the respective sample first catalysts SCF1 to SCF5 before the sulfuration treatment is shown in Figure 8. A temperature at which the maximum NO conversion efficiency (Cmax) was attained is indicated in Figure 8. As apparent from Figure 8, the sample first catalysts SCF1 and SCF3 to SCF6 before the sulfuration treatment show C300 and C250 NO conversion efficiency greater than the sample first catalysts SCF2 and SCF7 before the sulfuration treatment. It is also apparent that the sample first catalyst SCF4 shows maximum NO conversion efficiency slightly smaller than the sample first catalyst SCF1 and, however, shows C300 and C250 NO conversion efficiency greater than the sample first catalyst SCF1 and that the combinations of Ag and another catalytic metal are contributory to improving initial NO conversion efficiency of the first catalysts, in particular of the first catalyst SCF6. The first catalyst SCF5 show high initial NO conversion efficiency especially at higher temperatures.

[0069] In light of the result of NO conversion efficiency of the first catalysts before the sulfuration treatment, measurements of NO conversion efficiency were made for the first catalysts SCF1 and SCF3 to SCF6 after the sulfuration treatment, the result of which is shown in Figure 9. As apparent from Figure 9, the first catalyst

containing Ag in combination of Ce, Fe, Co or Ni after the sulfuration treatment shows significantly improved NO conversion efficiency as compared with the first catalyst containing Ag alone. The combination of Ag and Fe, Co or Ni is especially superior. This fact reveals that the combinations of Ag and another catalytic metal such as Ce, Fe, Co and Ni are contributory to improving NO conversion efficiency of the first catalysts after the sulfuration treatment.

[0070] It is therefore revealed from the above evaluation that the combination of catalytic metals, such as Ag in combination with Ag, Ce, Fe, Co or Ni, is effective in improving NO conversion efficiency and resistance to sulfuration of the first catalyst.

[0071] In order to study an effect of simultaneous impregnation or separate impregnation with catalytic metals on NO conversion efficiency of a first catalyst before and after the sulfuration treatment, measurements of C300, C250 and maximum NO conversion efficiency were made for various first catalysts.

[0072] The following sample first catalysts SCF8 to SCF13 were prepared.

Sample first catalyst SCF8: Co-Ce/FAU

[0073]

FAU zeolite as a base material was impregnated with a first catalytic metal Co and thereafter with a second catalytic metal Ce.

Sample first catalyst SCF9: Co-Ce/FAU

[0074]

FAU zeolite as a base material was impregnated with first and second catalytic metals Co and Ce, simultaneously.

Sample first catalyst SCF10: Ni-Ag/Al<sub>2</sub>O<sub>3</sub>

[0075]

γ-alumina as a base material was impregnated with a first catalytic metal Ag and thereafter with a second catalytic metal Ni.

Sample first catalyst SCF11: Co-Ag/Al<sub>2</sub>O<sub>3</sub>

[0076]

γ-alumina as a base material was impregnated with a first catalytic metal Ag and thereafter a second catalytic metal Co.

[0077] The respective sample first catalysts were prepared by the same manner for the sample first catalysts SCF1 - SCF7. Each of the sample first catalysts SCF8

and SCF9 coated on a honeycomb substrate contained 120 g/L base material, 0.88 mol/L Co and 0.44 mol/L Ce. Each of the sample first catalysts SCF10 and SCF11 coated on a honeycomb substrate contained 120 g/L base material, 30 g/L Ag, and 0.44 mol/L Ni or 0.44 mol/L Co. The results of measurements of C300, C250 and maximum NO conversion efficiency of the respective sample first catalysts SCF8 to SCF11 before and after the sulfuration treatment are shown in Figures 10 and 11, respectively. C300, C250 and maximum NO conversion efficiency of the respective sample first catalysts SCF5 and SCF6 before and after the sulfuration treatment are incorporated in Figures 10 and 11, respectively.

[0078] As apparent from Figures 10 and 11, while separate impregnation with two catalytic metals improves NO conversion efficiency of the first catalyst and, however, is inferior in improvement of NO conversion efficiency of the first catalyst to simultaneous impregnation with two catalytic metals. This is considered from the reason that the second catalytic metal Ce, Ni or Co which is used in combination with a first catalytic metal Ag or Co exhibits its catalytic effect as a result of a uniform mix of the first and second catalytic metals at level of atom rather than a result of physically covering up the first catalytic metal with the second catalytic metal.

[0079] Figure 12 shows a double layer first catalyst according to another embodiment of the invention. A double layer first catalyst comprises a first catalytic metal under layer 5 formed on a honeycomb substrate 4 and a second catalytic metal over layer 6 formed over the first catalytic metal layer 5. The first catalytic metal under layer 5 comprises a layer of a mixture of a base material and binder coated on the honeycomb substrate 5 and impregnated with a first catalytic metal. The second catalytic metal over layer 6 comprises a layer of a mixture of an oxide of a second catalytic metal and binder coated over the first catalytic metal under layer 5.

[0080] Evaluation of performance of the double layer first catalyst was made by measuring C300, C250 and maximum NOx and HC purification efficiency. The following sample double layer first catalyst SCF14 to SCF19 were prepared.

Sample double layer first catalyst SC14:  
Ag/CeO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub>

[0081]

Under layer: Ag/Al<sub>2</sub>O<sub>3</sub>

γ-alumina as a base material was impregnated with Ag as a first catalytic metal

Over layer: CeO<sub>2</sub>

A layer of CeO<sub>2</sub> as an oxide of Ce as a second catalytic metal was formed over the under layer

Sample double layer first catalyst SC15:

Ag/MnO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub>

[0082]

Under layer: Ag/Al<sub>2</sub>O<sub>3</sub>

γ-alumina as a base material was impregnated with Ag as a first catalytic metal

Over layer: MnO<sub>2</sub>

A layer of MnO<sub>2</sub> as an oxide of Mn as a second catalytic metal was formed over the under layer

Sample double layer first catalyst SC16: Ag/FeO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub>

[0083]

Under layer: Ag/Al<sub>2</sub>O<sub>3</sub>

γ-alumina as a base material was impregnated with Ag as a first catalytic metal

Over layer: FeO<sub>2</sub>

A layer of FeO<sub>2</sub> as an oxide of Fe as a second catalytic metal was formed over the under layer

Sample double layer first catalyst SC17: Ag/CoO/Al<sub>2</sub>O<sub>3</sub>

[0084]

Under layer: Ag/Al<sub>2</sub>O<sub>3</sub>

γ-alumina as a base material was impregnated with Ag as a first catalytic metal

Over layer: CoO

A layer of CoO as an oxide of Co as a second catalytic metal was formed over the under layer

Sample double layer first catalyst SC18: Ag/NiO/Al<sub>2</sub>O<sub>3</sub>

[0085]

Under layer: Ag/Al<sub>2</sub>O<sub>3</sub>

γ-alumina as a base material was impregnated with Ag as a first catalytic metal

Over layer: NiO

A layer of NiO as an oxide of Ni as a second catalytic metal was formed over the under layer

Sample double layer first catalyst SC19: Ag/CuO/Al<sub>2</sub>O<sub>3</sub>

[0086]

Under layer: Ag/Al<sub>2</sub>O<sub>3</sub>

γ-alumina as a base material was impregnated with Ag as a first catalytic metal

Over layer: CuO

A layer of CuO as an oxide of Cu as a second catalytic metal was formed over the under layer

[0087] The respective sample double layer first catalysts were prepared by dipping an Ag/Al<sub>2</sub>O<sub>3</sub> under layer

prepared by the manner for preparing the Ag/Al<sub>2</sub>O<sub>3</sub> first catalyst described above in and drawing from a slurry of a mixture of an oxide of a second catalytic metal, binder and water to form an over layer of an oxide of the second catalytic metal. The double layer first catalyst was blown dry and then calcined at 500°C for two hours in an electric furnace. Each of the sample double layer first catalysts SCF14 to SCF19 formed on the honeycomb substrate contained 120 g/L base material, 30 g/L first catalytic metal, i.e. Ag, and 0.5 mol/L second catalytic metal.

[0088] NOx purification efficiency measurements were made under the same condition in which the inlet temperature of simulated exhaust gas was increased at a rate of 30°C/min after holding the simulated exhaust gas at 160°C for five minutes. The result of C300 NOx purification efficiency and Cmax temperature measurements of the sample double layer first catalysts SCF14 to SCF19 before and after the sulfuration treatment is summarized in Figures 13 and 14, respectively. C300, C250 and maximum NO conversion efficiency of a comparative single layer exhaust gas purifying catalyst CC24 comprising an Ag/Al<sub>2</sub>O<sub>3</sub> under layer only are incorporated in Figures 13 and 14. As apparent from Figures 13 and 14, only the sample double layer first catalyst SCF17 shows C300, C250 and maximum NO conversion efficiency before and after the sulfuration treatment higher than the comparative single layer exhaust gas purifying catalyst CC24, and the remaining sample double layer first catalysts SCF14 to SCF16, SCF18 and SCF19 show C300, C250 and maximum NO conversion efficiency before and after the sulfuration treatment lower than the comparative single layer exhaust gas purifying catalyst CC24. This fact reveals that the double layer first catalyst which is effective in converting NO to NO<sub>2</sub> is one comprising an over layer of an oxide of Co as a second catalytic metal.

[0089] As described above, with respect to C300, C250 and maximum NO conversion efficiency before and after the sulfuration treatment, the Ag-Ni/Al<sub>2</sub>O<sub>3</sub> first catalyst SCF6 which is impregnated with first and second catalytic metals Ag and Ni, simultaneously, is most superior to the remaining first catalyst. In light of this, C300, C250 and maximum NO conversion efficiency measurements before and after the sulfuration treatment were made for Ag-Ni/Al<sub>2</sub>O<sub>3</sub> first catalysts having different Ni contents under the same condition in which the inlet temperature of simulated exhaust gas was increased at a rate of 30°C/min after holding the simulated exhaust gas at 160°C for five minutes. NOx purification efficiency measurements were made under the same condition in which the inlet temperature of simulated exhaust gas was increased at a rate of 25°C/min after holding the simulated exhaust gas at 160°C for five minutes. Figure 15 shows the result of measurements of C250 and maximum NOx purification efficiency with respect to Ni content for Ag-Ni/Al<sub>2</sub>O<sub>3</sub> first catalysts containing Ni and 30 g/L Ag before and after the sulfuration

treatment. As apparent from Figure 15, C250 and maximum NOx purification efficiency has peaks at an approximately 26 g/L Ni content when the Ag-Ni/Al<sub>2</sub>O<sub>3</sub> first catalyst is before the sulfuration treatment and at an approximately 39 g/L Ni content when the Ag-Ni/Al<sub>2</sub>O<sub>3</sub> first catalyst is after the sulfuration treatment. This facts reveals that, for the Ag-Ni/Al<sub>2</sub>O<sub>3</sub> first catalyst containing 30 g/L Ag, the Ni content is preferred to be between 20 and 50 g/L, and more specifically between 25 and 40 g/L. Figure 16 shows the result of measurements of C250 and maximum NOx purification efficiency with respect to Ag content for Ag-Ni/Al<sub>2</sub>O<sub>3</sub> first catalysts containing Ag and 26 g/L Ni before and after the sulfuration treatment. As apparent from Figure 16, it is revealed that, for the Ag-Ni/Al<sub>2</sub>O<sub>3</sub> first catalyst containing 26 g/L Ni, the Ag content is preferred to be between 20 and 60 g/L, and more specifically between 30 and 60 g/L.

[0090] From the above evaluation, the Ag-Ni/Al<sub>2</sub>O<sub>3</sub> first catalysts is preferred to contain 20 to 60 g/L Ag or more specifically 30 to 60 g/L Ag and 20 to 50 g/L Ni or more specifically 25 to 50 g/L Ni.

[0091] It is to be understood that although the present invention has been described with regard to preferred embodiments thereof, various other embodiments and variants may occur to those skilled in the art, which are within the scope and spirit of the invention, and such other embodiments and variants are intended to be covered by the following claims.

#### Claims

1. An exhaust gas purifying catalyst (1) characterized by a first catalyst (2) for oxidizing NO to NO<sub>2</sub> and a second catalyst (3) for reducing the oxidized NO<sub>2</sub> to N<sub>2</sub>.
2. The exhaust gas purifying catalyst as defined in claim 1, wherein said second catalyst clacks HC having a large carbon number to HC having a small carbon number and causes the clacked HC to react with NO<sub>2</sub> so as thereby to reduce the NO<sub>2</sub>.
3. The exhaust gas purifying catalyst as defined in claim 2, wherein said first catalyst (2) contains at least one selected out of catalytic metals Ag, Co and Mn.
4. The exhaust gas purifying catalyst as defined in claim 3, wherein said catalytic metal of said first catalyst (2) is supported on at least one of base materials including alumina, mesopore silicate and FAU.
5. The exhaust gas purifying catalyst as defined in claim 3, wherein said first catalyst (2) further contains at least one selected out of catalytic metals Ni, Ce, Rh and Fe.
6. The exhaust gas purifying catalyst as defined in claim 2, wherein said first catalyst is supported on a substrate and contains 20 to 60 g per one liter of said substrate and 20 to 50 g per one liter of said substrate as catalytic metals.
7. The exhaust gas purifying catalyst as defined in claim 2, wherein said first catalyst comprises an under catalyst layer containing Ag as a catalytic metal coated on a substrate and an over catalyst layer containing Co as a catalytic metal coated over said under catalyst layer.
8. The exhaust gas purifying catalyst as defined in any one of said proceeding claims 2 through 6, wherein said second catalyst contains a catalytic metal supported on a metal silicate through ion exchange.
9. The exhaust gas purifying catalyst as defined in claim 8, wherein said catalytic metal contained in said second catalyst comprises a noble metal.
10. The exhaust gas purifying catalyst as defined in claim 1, wherein said catalyst contains at least one selected out of catalytic metals Ag and Co and at least one selected out of Ni and Ce.
11. The exhaust gas purifying catalyst as defined in claim 1, wherein said catalyst containing 15 to 150 g per one liter of said substrate of Ag supported on alumina as a base material.
12. The exhaust gas purifying catalyst as defined in claim 1, wherein said catalyst (1) contains Ag and at least one selected out of Ni, Ce, Rh, Ce and Fe.
13. An exhaust gas purifying catalyst characterized by:
  - a first catalyst (5) containing at least one selected out of catalytic metals Ag, Co and Mn; and
  - a second catalyst (6) containing a noble metal supported on metal silicate through ion exchange.
14. The exhaust gas purifying catalyst as defined in claim 13, wherein said first catalyst (5) contains Ag as said catalytic metal and said first and second catalysts (5, 6) are formed as individual layers on a substrate (4).
15. The exhaust gas purifying catalyst as defined in claim 14, wherein said layer of said second catalyst (6) is formed over said layer of said first catalyst (5) on said substrate.

Fig. 1

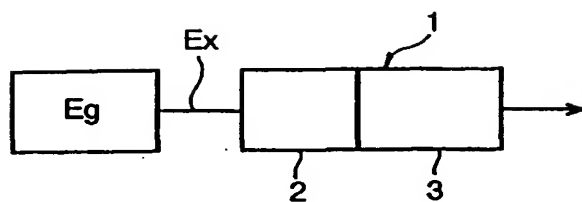


Fig. 2

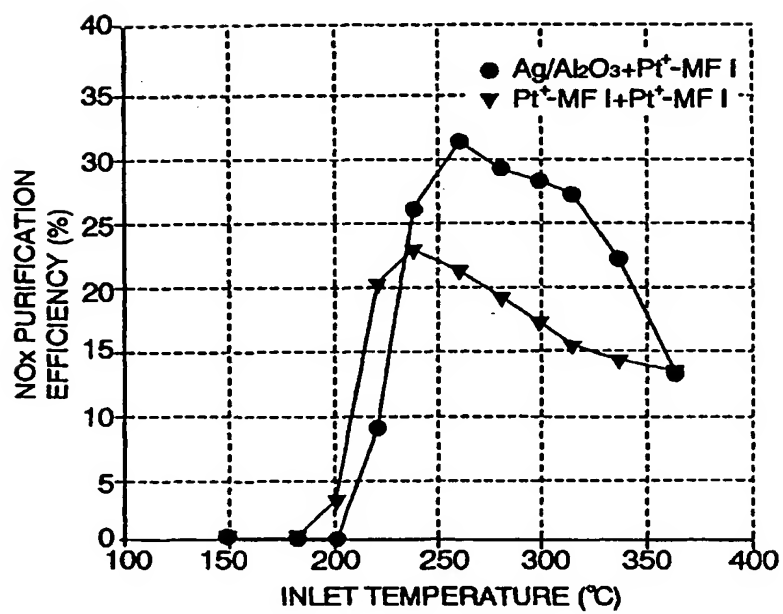


Fig. 3

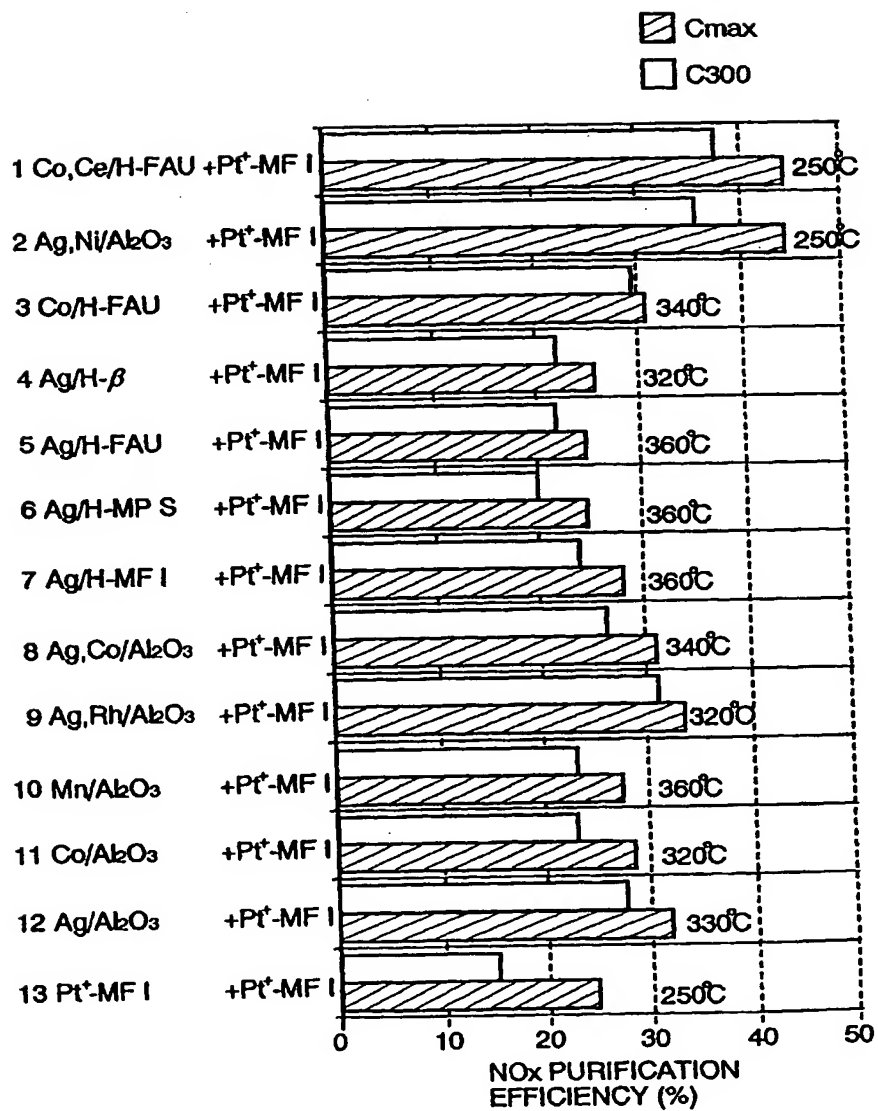


Fig. 4

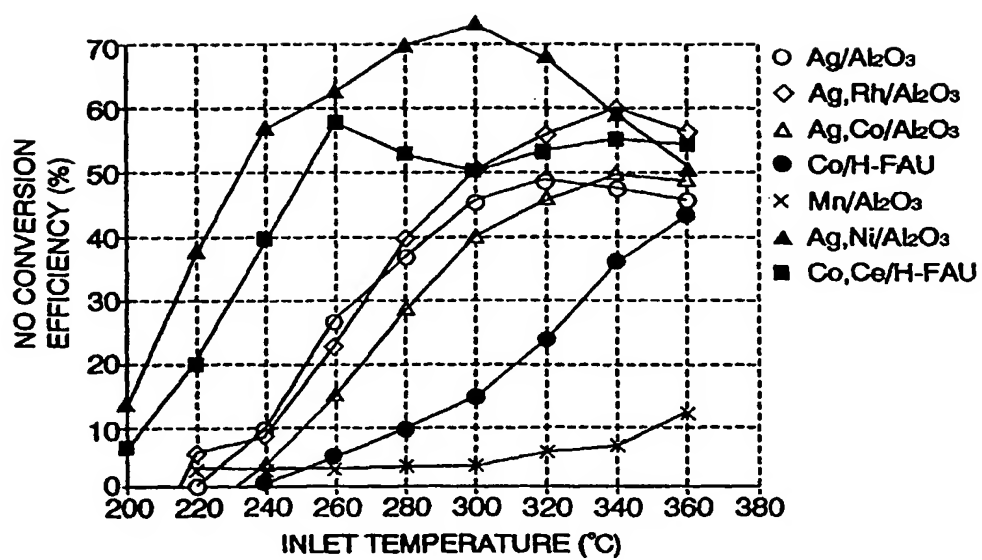


Fig. 5

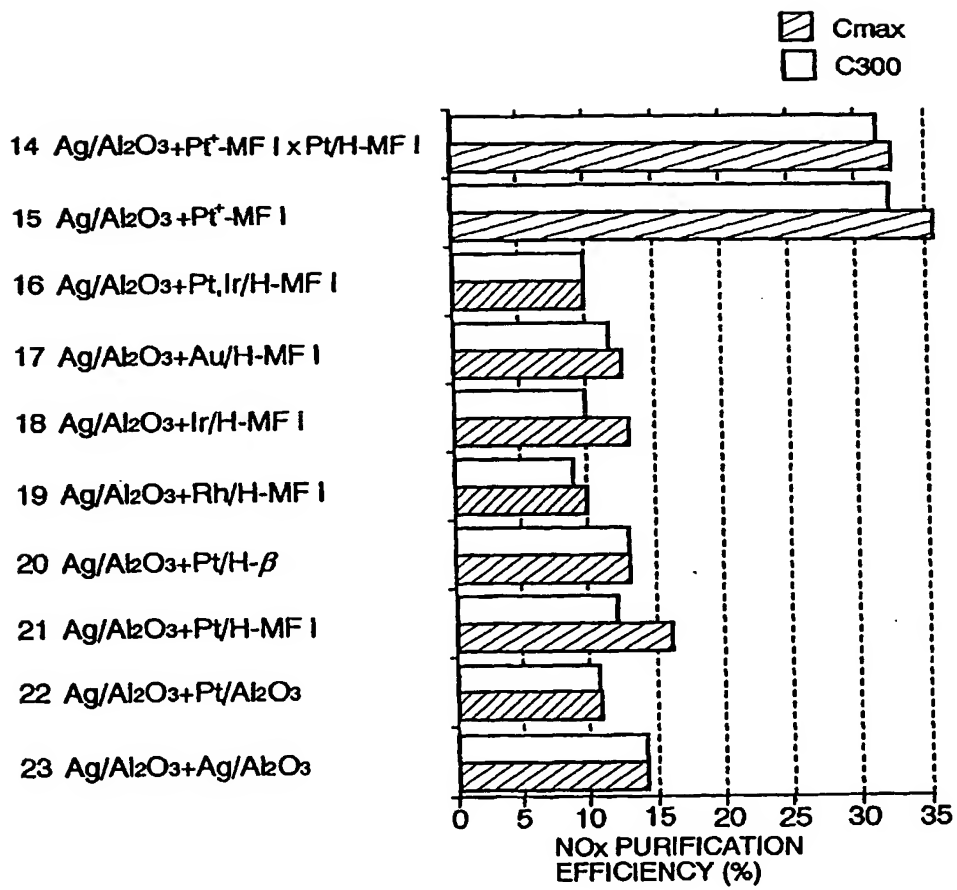




Fig. 6

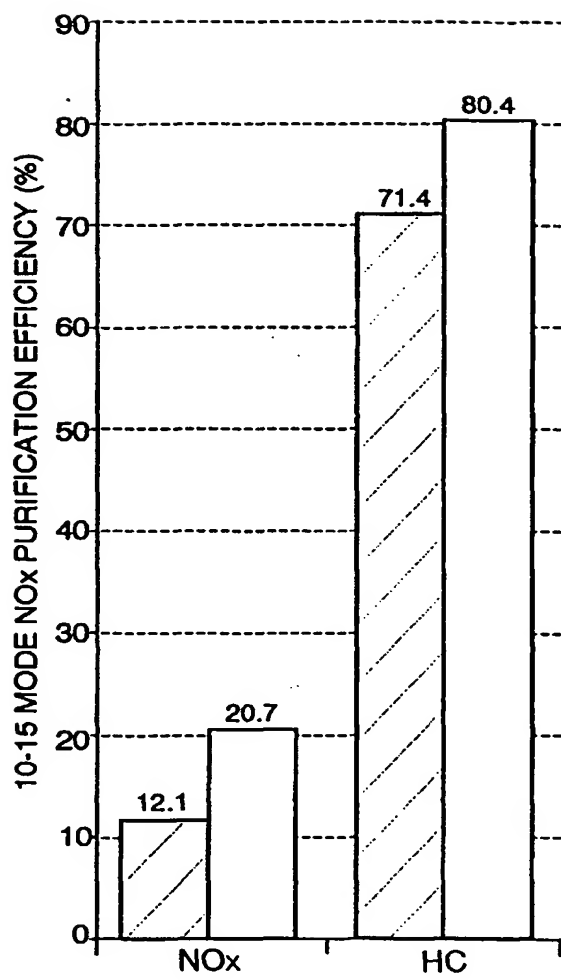
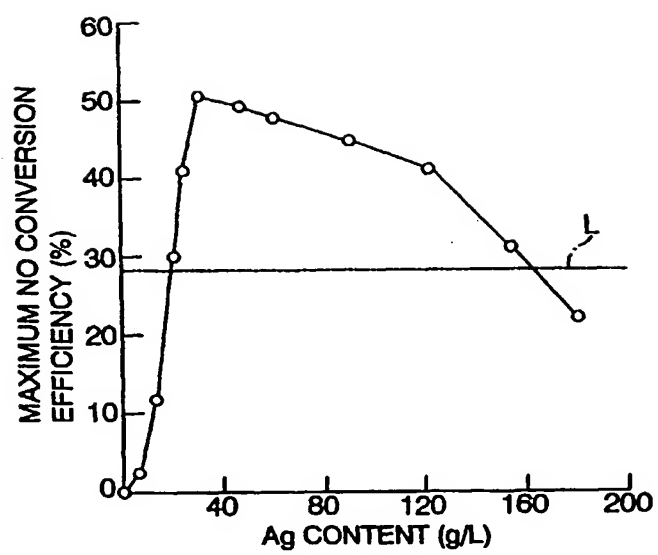


Fig. 7



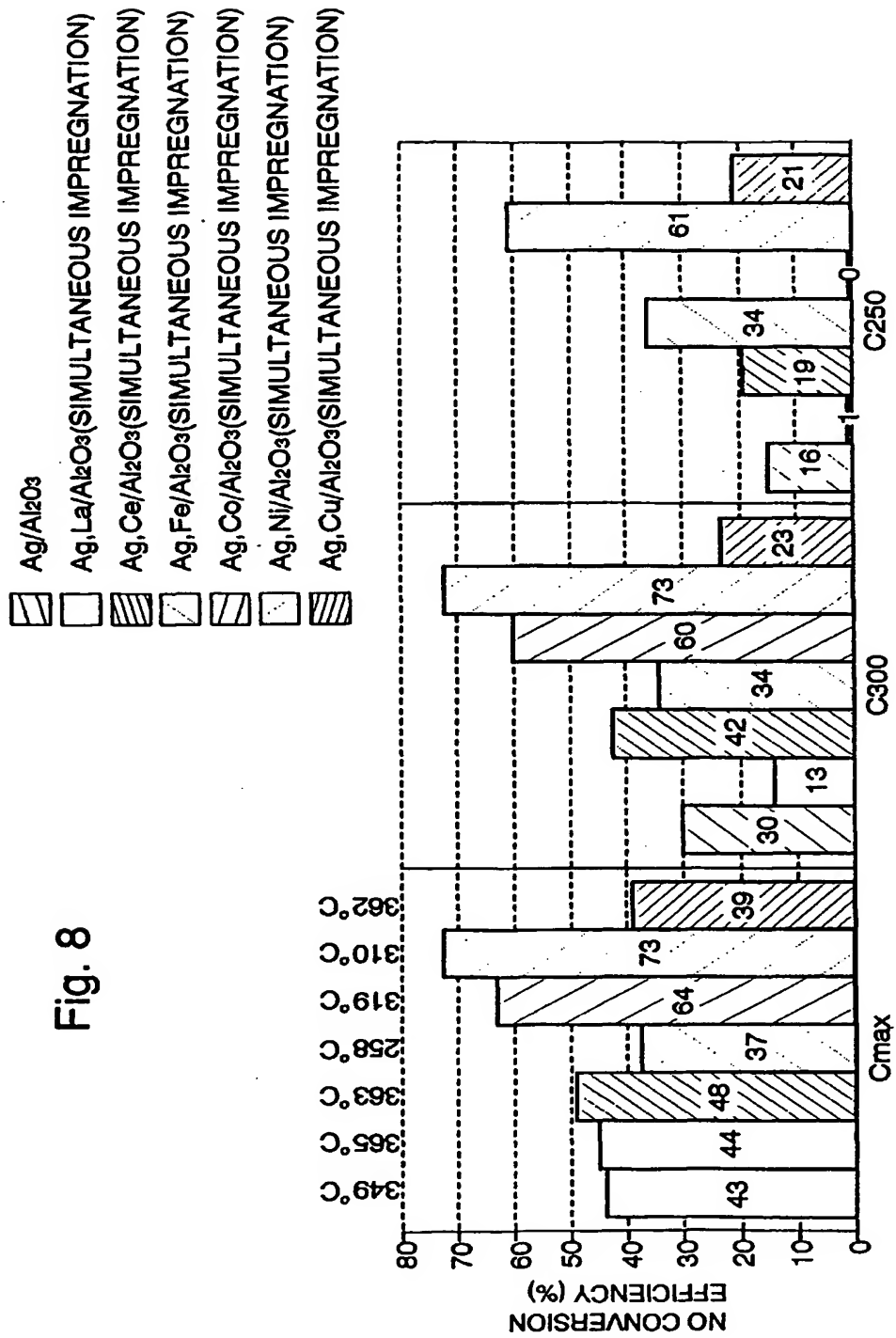
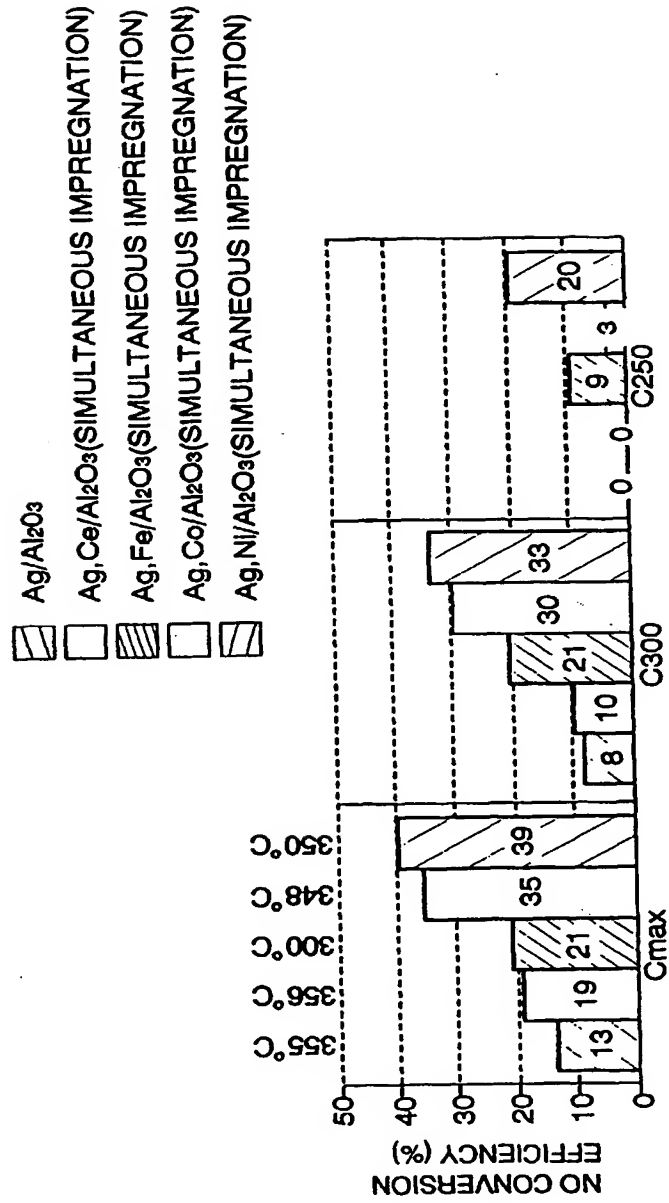


Fig. 9









-  Ce/Co/FAU(SEPARATE IMPREGNATION)  
 Co,Ce/FAU(SIMULTANEOUS IMPREGNATION)  
 Ni/Ag/Al<sub>2</sub>O<sub>3</sub>(SEPARATE IMPREGNATION)  
 Ni,Ag/Al<sub>2</sub>O<sub>3</sub>(SIMULTANEOUS IMPREGNATION)  
 Co/Ag/Al<sub>2</sub>O<sub>3</sub>(SEPARATE IMPREGNATION)  
 Co,Ag/Al<sub>2</sub>O<sub>3</sub>(SIMULTANEOUS IMPREGNATION)

Fig. 10

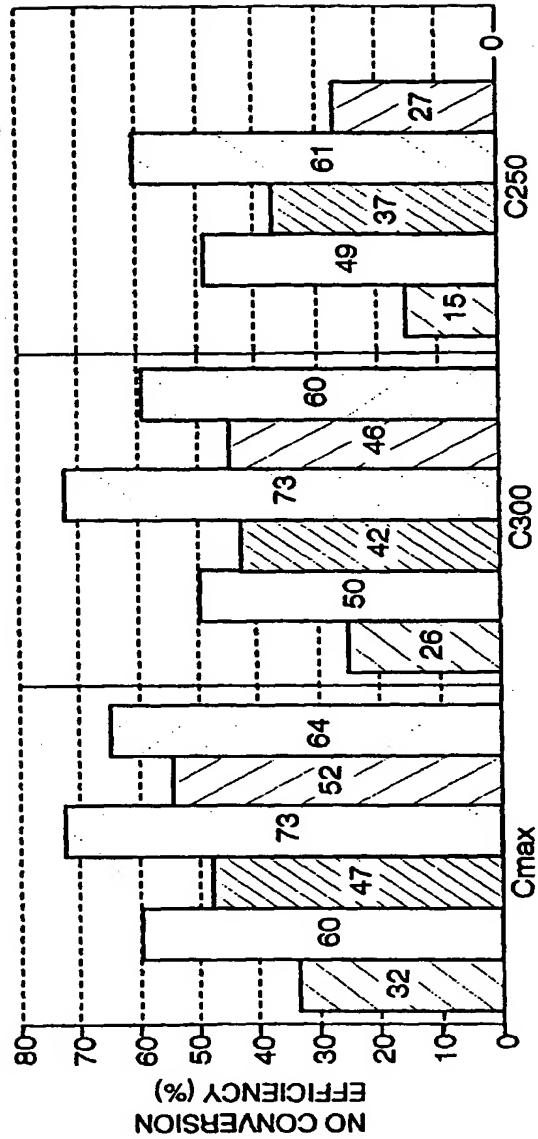


Fig. 11

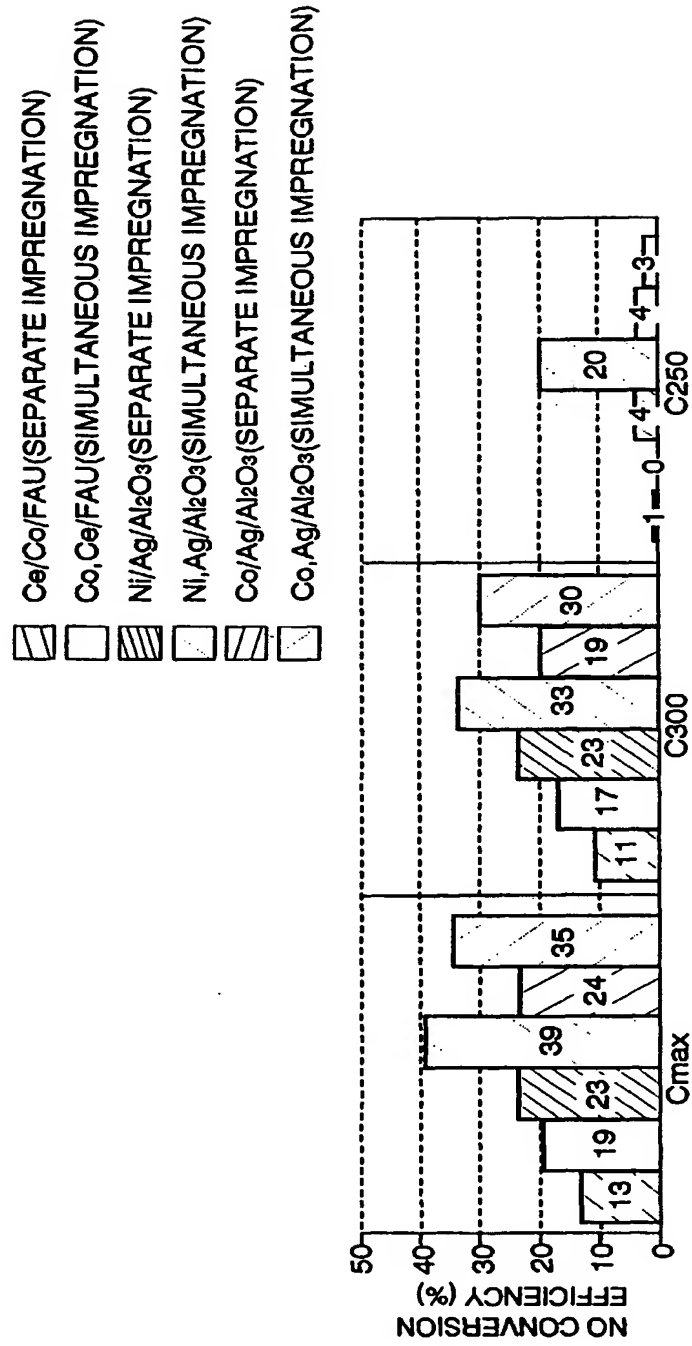
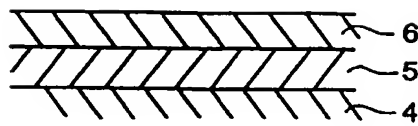


Fig. 12



**Fig. 13**

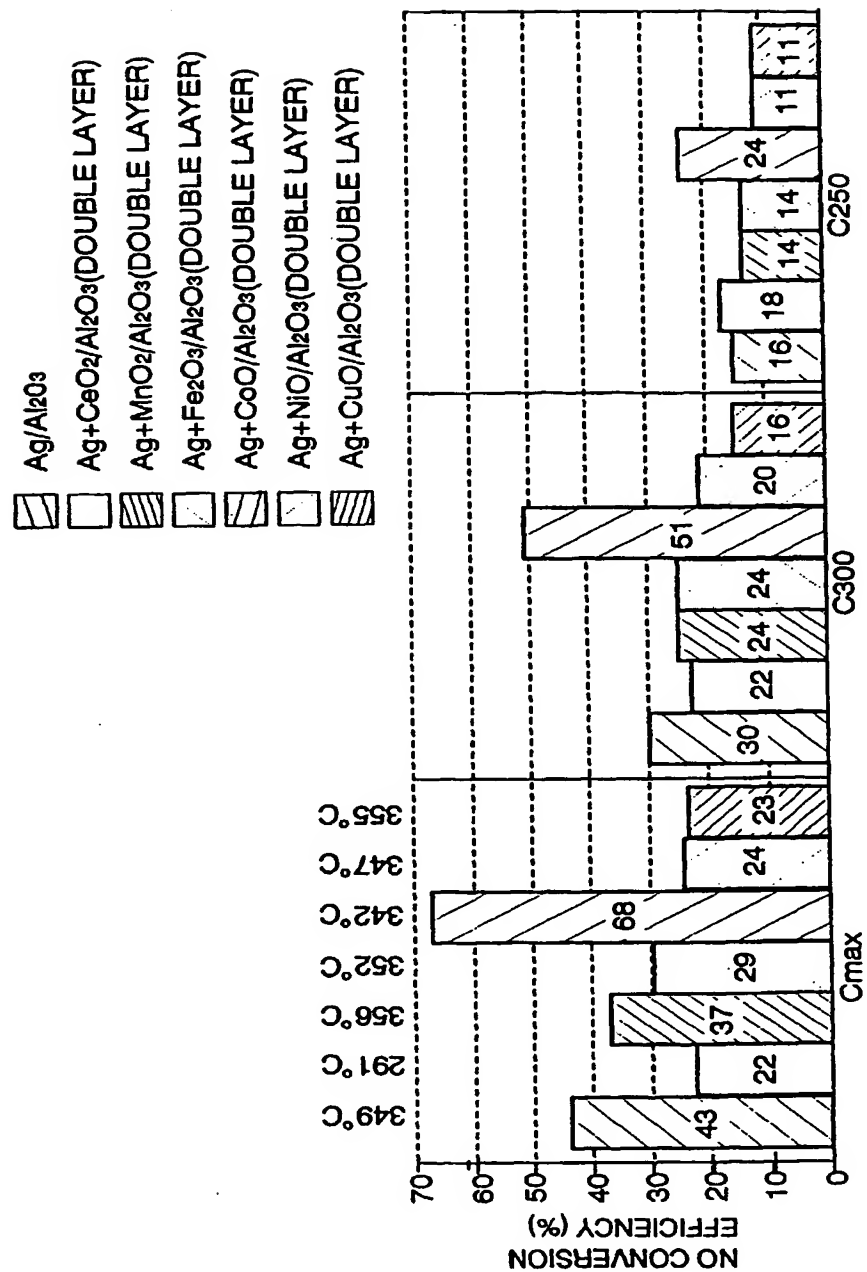




Fig. 14

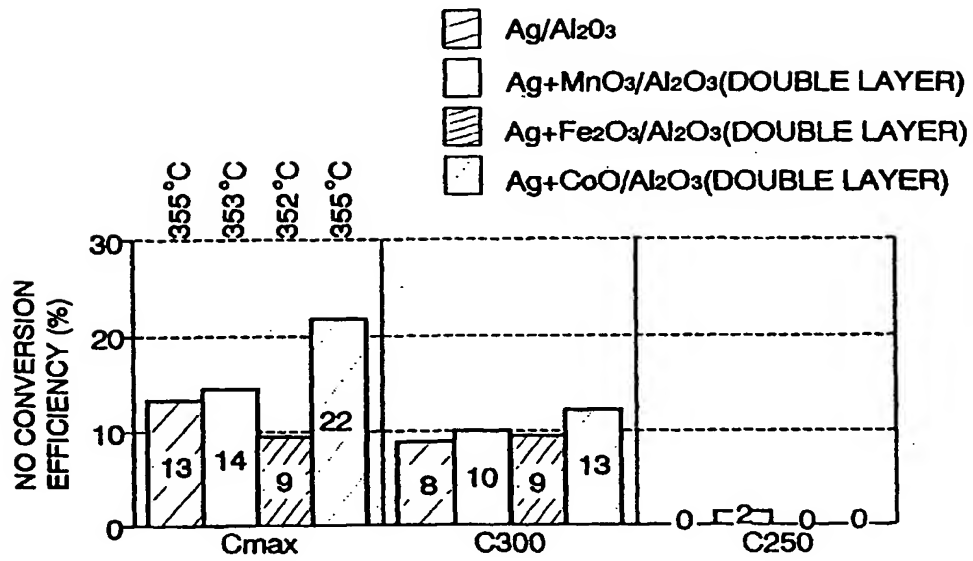


Fig. 15

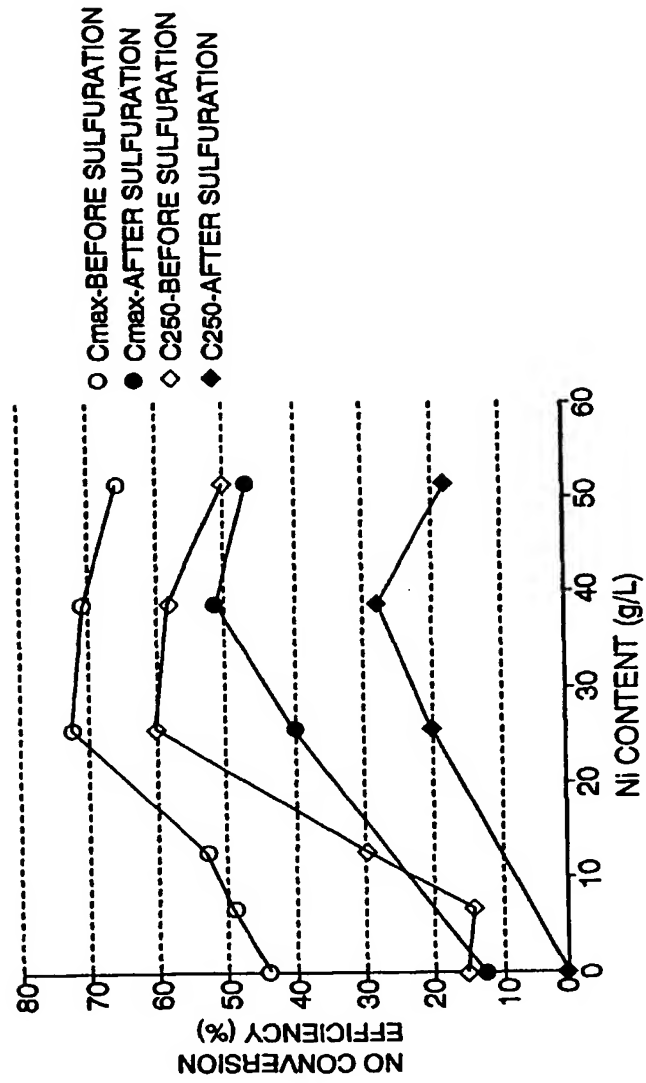
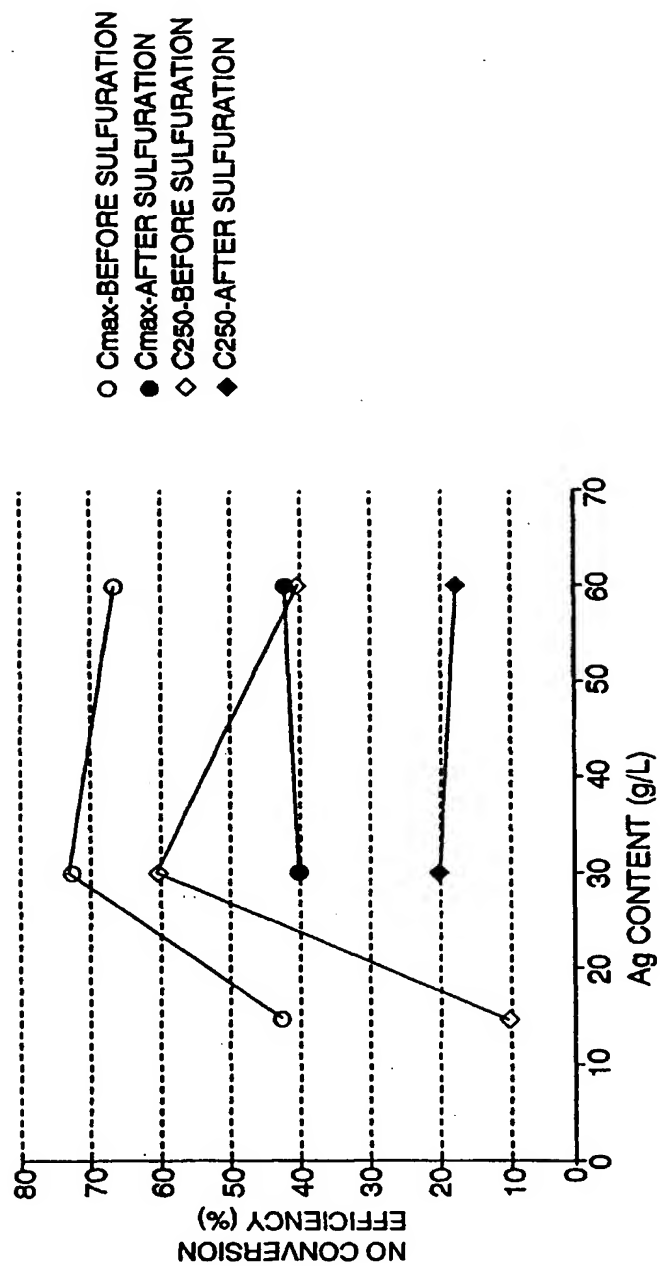


Fig. 16



Application Number  
EP 99 10 6526



European Patent  
Office

# EUROPEAN SEARCH REPORT

Application Number  
EP 99 10 6526

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
D,X	PATENT ABSTRACTS OF JAPAN vol. 098, no. 003, 27 February 1998 (1998-02-27) & JP 09 299795 A (TOYOTA CENTRAL RES & DEV LAB INC), 25 November 1997 (1997-11-25) * abstract *	1,4,9	
A	US 5 409 671 A (TAKEMOTO TAKASHI ET AL) 25 April 1995 (1995-04-25) * claims 1-11 *	1,3, 7-10, 12-15	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
Place of search BERLIN		Date of completion of the search 27 July 1999	Examiner Cubas Alcaraz, J
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons &amp; : member of the same patent family, corresponding document</p>			

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 99 10 6526

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
The members are as contained in the European Patent Office EDP file on  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

27-07-1999

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0719580 A	03-07-1996	JP 8182931 A	16-07-1996
		JP 8229352 A	10-09-1996
		JP 8229353 A	10-09-1996
		JP 8229393 A	10-09-1996
		JP 8276131 A	22-10-1996
		US 5741468 A	21-04-1998
EP 0710499 A	08-05-1996	JP 2649217 B	03-09-1997
		JP 8131778 A	28-05-1996
		JP 2700386 B	21-01-1998
		JP 8182920 A	16-07-1996
		JP 8150336 A	11-06-1996
		US 5882607 A	16-03-1999
JP 63049255 A	02-03-1988	JP 2529214 B	28-08-1996
EP 0533460 A	24-03-1993	JP 5086849 A	06-04-1993
		DE 69203311 D	10-08-1995
		DE 69203311 T	09-11-1995
		US 5313792 A	24-05-1994
JP 09299795 A	25-11-1997	NONE	
US 5409671 A	25-04-1995	JP 5168939 A	02-07-1993

For more details about this annex - see Official Journal of the European Patent Office, No. 12/92